NASA STTR 2021 Phase I Solicitation

T6.06 Enabling Spacecraft Water Monitoring through Nanotechnology

Lead Center: JSC

Participating Center(s): ARC, GRC, JPL, KSC, MSFC

Scope Title:

Monitoring Systems for Inorganic and Organic Analytes in Spacecraft Water Streams

Scope Description:

This subtopic solicits for technologies that fill specific gaps in capabilities needed for spacecraft water management in the area of environmental monitoring. Its focus is on technologies that identify and quantify inorganic and organic species in water for use during long-duration human missions away from Earth. This subtopic is aligned with the thrust "Enabling Next-Generation Water Monitoring Systems with Nanotechnology," described within a white paper of the Nanotechnology Signature Initiative (NSI) "Water Sustainability through Nanotechnology."

NASA is seeking miniature analytical systems to measure mineral and organic constituents in potable water and wastewater. NASA is interested in sensor suites capable of simultaneous measurement of inorganic or organic species. There is interest in the capability for monitoring species within wastewater, regenerated potable water, thermal control system cooling water, and samples generated from science activities and biomedical operations. Potential wastewater streams, both current and possible in the future, include urine, urine brines, humidity condensate, Sabatier and Bosch product water, wastewater from hygiene, and wastewater from laundry. Multispecies analyte measurement capability is of interest that would provide a similar capability to that available from standard water monitoring instruments such as ion-chromatography, inductively coupled plasma spectroscopy, and high-performance liquid chromatography. Components that enable the miniaturization of these monitoring systems, such as microfluidics and small scale detectors, will also be considered.

Technologies should be targeted to have >3-year service life and at least >50% size reduction compared to current state of the art. Ideally, monitoring systems should require no hazardous reagents, have long-term calibration stability, can be recalibrated in flight, require few consumables, and require very little crew time to operate and maintain. The proposed analytical instrument should be compact, require minimal sample preparation, be compatible with microgravity and partial gravity, and be power efficient. Sample volumes should be minimized and should be identified within the proposal.

Monitoring capability is of interest for both identification and quantification of organic and inorganic contaminants, including polyatomic ions and unknowns. Examples of species of interest and their levels for measurement are specified in Spacecraft Water Exposure Guidelines (SWEGs), released as JSC 63414 (last revised July 2017). Targeted inorganic compounds identified in the SWEGs for human exploration missions include ammonium, antimony, barium, cadmium, manganese, nickel, silver, and zinc. But there is also interest in measurement of other cations and anions including iron, copper, aluminum, chromium, calcium, magnesium, sodium, potassium, arsenic, lead, molybdenum, fluoride, bromide, boron, silicon, lithium, phosphates, sulfates, chloride, iodine, nitrate, and nitrite. Examples of organics include benzene, caprolactam, chloroform, phthalates, dichloromethane, dimethylsilanediol, glycols, aldehydes, formate, 2-mercaptobenzothiozole, alcohols, ketones, and phenol, N-phenyl-beta-naphthylamine.

Please see references for additional information, including NASA's water quality requirements and guidelines, and the current state of the art in spacecraft water management, including recycling wastewater.

Expected TRL or TRL Range at completion of the Project: 2 to 4
Primary Technology Taxonomy:
Level 1: TX 06 Human Health, Life Support, and Habitation Systems
Level 2: TX 06.4 Environmental Monitoring, Safety, and Emergency Response
Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype
- Hardware

Desired Deliverables Description:

Phase I Deliverablesâ€”Reports demonstrating proof of concept, including test data from proof-of-concept studies, and concepts and designs for Phase II. In addition, Phase I tasks should answer critical questions focused on reducing development risk prior to entering Phase II.

Phase II Deliverablesâ€”Delivery of technologically mature hardware, including components and subsystems that demonstrate performance over the range of expected spacecraft conditions. Hardware should be evaluated through parametric testing prior to shipment. Reports should include design drawings, safety evaluation, and test data and analysis. Prototypes must be full scale unless physical verification in 1g is not possible. Robustness must be demonstrated with long-term operation and with periods of intermittent dormancy. System should incorporate safety margins and design features to provide safe operation upon delivery to a NASA facility.

State of the Art and Critical Gaps:

There is limited capability for water quality analysis onboard current spacecraft. Simple measurements of water composition are made on the ISS during flight, and these are limited to conductivity, total organic carbon and iodine concentration. For identification and characterization of ionic or organic species in water and wastewater, samples currently must be returned to Earth.

Water recovery from wastewater sources is considered enabling to long-duration human exploration missions away from Earth. Without substantial water recovery, life support system launch weights are prohibitively large. Regenerative systems are utilized on the International Space Station (ISS) to recycle water from humidity condensate, Sabatier product water, and urine into potable water (see ICES-2019-36 for more information). Several hardware failures have occurred onboard the ISS, which demonstrate the need for in situ measurement of inorganic and organic contaminants (for examples, see ICES-2018-123 and ICES-2018-87). This will be especially important for human exploration missions in deep space where return of samples to Earth for analysis on the ground will be impossible. Spacecraft water analysis capability will also benefit onboard science, biomedical, and spacecraft maintenance operations. It will be necessary to confirm that potable water systems are safe for human use following periods of spacecraft dormancy (ICES-2017-43).

NASA has unique water needs in space that have analogous applications on Earth. NASAâ€™s goal is zero-discharge water treatment, targeting 100% water recycling and reuse. NASAâ€™s wastewater collection differs from systems used on Earth in that it is highly concentrated with respect to urine, uses minimal flush water, is separated from solid wastes, and contains highly acidic and toxic pretreatment chemicals. NASA is interested in recovery of potable water from wastewater, low toxicity residual disinfection, antifouling treatments for plumbing lines and tanks, "microbial check valves" that prevent microbial cross-contamination where water treatment and potable water systems share connections, and miniaturized sensors and monitoring systems for contaminants in potable water and wastewater. Only the last gap, technologies to monitor contaminants in water, is requested in this subtopic. Spacecraft traveling away from Earth require the capability of a fully functional water analysis laboratory, including identification and quantification of known and unknown inorganic ions, organics, and microbes, as well as pH, conductivity, total organic carbon, and other typical measurements. SWEGs have been published for selected contaminants. Nanotechnology may offer solutions in all of these application areas.

Relevance / Science Traceability:

Technologies developed under this subtopic could be proven on the ISS and would be enabling to long-duration human exploration missions away from Earth, including Gateway and exploration of the Moon and Mars, including both surface and transit.

This subtopic is directed at needs identified by the Environmental Control and Life Supportâ€”Crew Health and Performance Systems Leadership Team (ECLS-CHP SLT) in areas of water management and environmental monitoring.

This subtopic is directed at meeting NASA's commitments as a collaborating agency with the National Nanotechnology Signature Initiative: "Water Sustainability through Nanotechnology." This initiative was established under the NTSC Committee on Technology, Subcommittee on Nanoscale Science, Engineering and Technology.

References:

- NASA is a collaborating agency with the NTSC Committee on Technology Subcommittee on Nanoscale Science, Engineering and Technology's Nanotechnology Signature Initiative (NSI): "Water Sustainability through Nanotechnology" (Water NSI). For a white paper on the NSI, see https://www.nano.gov/node/1580
- A high-level overview of NASA's spacecraft water management was presented at a webinar sponsored by the Water NSI: "Water Sustainability through Nanotechnology: A Federal Perspective, October 19, 2016" https://www.nano.gov/publicwebinars
- A general overview of the state of the art of spacecraft water monitoring and technology needs was presented at a webinar sponsored by the Water NSI: "Water Sustainability through Nanotechnology: Enabling Next-Generation Water Monitoring Systems, January 18, 2017" located at https://www.nano.gov/publicwebinars
- For a list of targeted contaminants and constituents for water monitoring, see "Spacecraft Water Exposure Guidelines for Selected Waterborne Contaminants, JSC 63414" located at https://www.nasa.gov/feature/exposure-guidelines-smacs-swegs
- 2020 NASA Technology Taxonomy, TX06: Human Health, Life Support, and Habitation Systems, TX06.4.1, Sensors: Air, Water, Microbial, and Acoustic https://www.nasa.gov/sites/default/files/atoms/files/2020_nasa_technology_taxonomy.pdf
- Layne Carter, Jill Williamson, Daniel Gazda, Chris Brown, Ryan Schaezler, Frank Thomas, Jesse Bazley, Sunday Molina â€œStatus of ISS Water Management and Recovery,â€ 49th International Conference on Environmental Systems, ICES-2019-36 https://ttu-ir.tdl.org/handle/2346/84720
- Molly S. Anderson, Ariel V. Macatangay, Melissa K. McKinley, Miriam J. Sargusingh, Laura A. Shaw, Jay L. Perry, Walter F. Schneider, Nikzad Toomarian, Robyn L. Gatens "NASA Environmental Control and Life Support Technology Development and Maturation for Exploration: 2018 to 2019 Overview," 49th International Conference on Environmental Systems, ICES-2019-297 https://ttu-ir.tdl.org/handle/2346/84496
- Dean Muirhead, Layne Carter, Jill Williamson, Antja Chambers "Preventing

Precipitation in the ISS Urine Processor," 47th International Conference on Environmental Systems, ICES-2018-87 https://ttu-ir.tdl.org/handle/2346/74086

- Dean L. Muirhead, Layne Carter â€œDimethylsilanediol (DMSD) Source Assessment and Mitigation on ISS: Estimated Contributions from Personal Hygiene Products Containing Volatile Methyl Siloxanes (VMS)â€ 48th International Conference on Environmental Systems, ICES-2018-123 https://ttu-ir.tdl.org/handle/2346/74112
- Donald Layne Carter, David Tabb, Molly Anderson "Water Recovery System Architecture and Operational Concepts to Accommodate Dormancy," 47th International Conference on Environmental Systems, Paper ICES-2017-43 https://ttu-ir.tdl.org/handle/2346/72884

Several of the references may also be available at https://ntrs.nasa.gov